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Symposium Highlights*

Thomas Roser

Brookhaven National Laboratory, Upton
N.Y. 11973, USA

Abstract. Some of the highlights of the the 14th International Symposium on Spin Physics are presented with emphasis on recent and planned progress in experimental tools and facilities.

INTRODUCTION

It is a great pleasure to summarize the 14th International Symposium on Spin Physics which was in fact the first symposium to combine the series of Symposia on High Energy Spin Physics and on Polarization Phenomena in Nuclear Physics. The Symposium was opened by R. Jaffe who reminded everybody that 'All elementary particles and their interactions have spin'. In fact, we have yet to discover a spin zero particle with the elusive Higgs particle maybe being the first. Although spin is ubiquitous within particle physics the effects on experimental observations are often subtle and need very sophisticated tools, and it has been a sign of a mature field to focus on spin effects. This has been the case for nuclear and medium energy physics for some time now and more recently also included electro-weak processes and nucleon structure. The latter, in particular, marked the beginning of precision measurements of quantities that ultimately will test our understanding of strong (non-perturbative) Quantum-Chromo-Dynamics.

For these highlights I will focus on recent progress in experimental tools and facilities available to the investigation of spin effects. This is mainly due to fact that there were several excellent talks that summarized the status of spin physics theory and as well as my own background in experimental and accelerator physics. Many new facilities and tools were in fact presented at this conference which lets us anticipate exciting progress over the next few years. In anticipation of what is to come I organized this talk in terms of headlines that were generated during this symposium.

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POLARIZED RADIOACTIVE BEAMS AT RIKEN

The RIKEN radioactive beam facility has produced proton and neutron rich radioactive nuclei that acquire polarization during the producing fragmentation process. K. Asahi reported on a beautiful experimental set-up to measure the few percent beam polarization by stopping the radioactive nuclei and detecting the asymmetry in the weak β-decay. Finally the magnetic moment of these short-lived nuclei was measured to high precision using NMR techniques. The present beam energy of 130 MeV/amu is planned to be upgraded to about 400 MeV/amu.

HIGH ENERGY POLARIZED PHOTONS AT SPRING8

A new high energy polarized photon facility started operation at SPRING8. The photons are produced by compton back scattering from the 100 mA, 8 GeV electron beam using a high power 3.5 eV laser. T. Nakano layed out the plans to use the 2.4 GeV polarized photons with an intensity of about $2.5 \times 10^6 \gamma/s$ to explore photo production of exotic hadrons above the kaon threshold and to test the DHG sum rule using a polarized proton target in the future.

RECORD INTENSITY POLARIZED ELECTRON BEAM AT JLAB

UNPOLARIZED OPERATION TO END SOON

Responding to the demand for more polarized electron beam at JLab the new polarized electron source has delivered record intensity and polarization. Using the now standard method of producing polarized electrons with a circularly polarized laser from a strained GaAs photo-cathode 75% polarization and 50 - 75 microamps of electron beam was reached during the last run. This is expected to increase to about 100 microamps soon. At this intensity all operations at JLab can be satisfied with polarized beam although, in fact, most experiments already require polarized beam.

To monitor the beam polarization on-line and non-destructively a new compton polarimeter was developed as reported by T. Pussieux in the parallel sessions. To achieve the required laser intensity a Fabry-Perot laser cavity was successfully commissioned. It will now be possible to measure the beam polarization with an accuracy of about 2% for a 40 microamps, 4 GeV electron beam.

Several experiments are using the intense polarized electron beam. H. Gao described measurements of the spin transfer coefficient of the reaction ${}^1H(e, e'p)$, which allows the determination of the ratio of the electric to magnetic form factor. The new data covers a Q^2 range up to 3.5 GeV^2 and is much more precise than previous data.

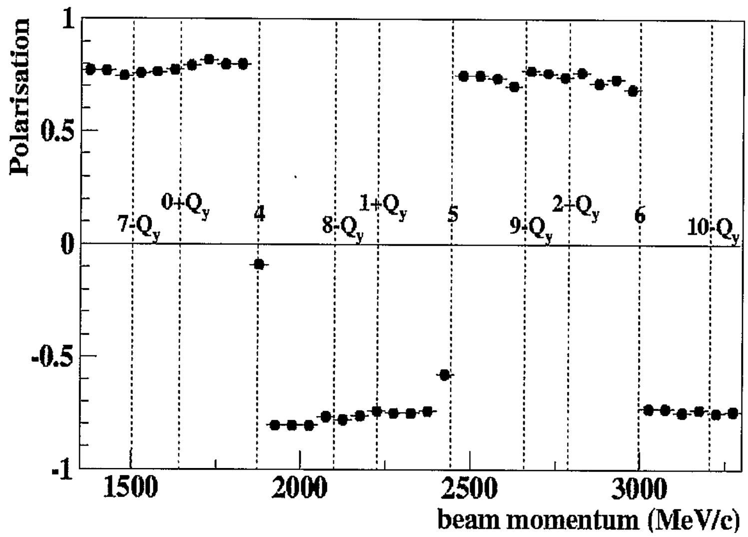

FIGURE 1. Beam polarization achieved at COSY using tune jumps to cross the spin resonances

P. Souder discussed the measurement of the weak nucleon form factor using parity violation in electron proton scattering. Through the coupling of the Z boson to the sea quarks this gives access to the strange radius and magnetic moment of the proton. Two experiments are presently under way: HAPPEX at JLAB and SAMPLE at Bates. The results indicate a small and positive strange magnetic moment and already rule out several of the proposed theoretical models.

HIGHLY POLARIZED BEAMS AT COSY

F. Hinterberger provided an update in the polarized proton acceleration at COSY. As shown in Fig.1 using a tune jump system to overcome the intrinsic resonances a proton beam momentum of 3.5 GeV/c was reached with about 75% polarization. After the closure of SATURNE medium energy polarized proton beams are now again available. The high quality polarized proton beam at COSY offers the opportunity to continue, at higher energy, the highly successful program of high precision experiments conducted at IUCF.

PHYSICISTS ARE EAGERLY AWAITING NEW RESULTS FROM "G-2"

Precise measurement of the anomalous magnetic moment of the muon is a very sensitive probe of corrections to QED. Electro-weak corrections are calculable and the hadronic contribution can be determined from electron-positron scattering. Any remaining difference constitutes a very sensitive probe of physics beyond the standard model. The experiment at BNL is measuring the difference between the spin and momentum precession in a highly homogenous magnetic field. G. Bunce showed beautiful precession data from the 1999 run with much more data from the 2000 run available but not yet analyzed. The so far collected data should give an accuracy of about 0.5 ppm which is about 20 times more accurate than the result from the previous CERN experiment.

POLARIZED PROTON SOURCES REACH RECORD INTENSITIES

Polarized proton sources have recently made tremendous progress. In two recent installations at IUCF and BNL, respectively, intensities of about 1 mA have been achieved. A. Belov described the new pulsed Atomic Beam Source at IUCF that reached a peak intensity of 1.5 mA and about 80% polarization. During his overview of the status of polarized sources A. Zelenski showed results from the new Optically Pumped Polarized Ion Source developed at TRIUMF and installed at BNL. It has already met the design intensity of 1×10^{12} polarized protons in a $300\mu s$ pulse. After many years of development both source techniques have now reached a very high level of performance and for many applications such as the RHIC collider operation the polarized source is not the intensity limiting component anymore.

POLARIZED PROTONS ACCELERATED TO HIGHEST ENERGY AT RHIC

PLANS FOR UNPOLARIZED OPERATION CANCELLED

The Relativistic Heavy Ion Collider (RHIC) at BNL has started operation this year with data collected at all four initial detectors. Although this first operation period was dedicated to colliding gold beams, preparations to collide polarized proton beams in RHIC, sponsored by RIKEN, have started and a first commissioning period with polarized protons was completed. Fig. 2 shows a lay-out of the hardware needed for polarized proton acceleration.

Of particular interest is the design of the Siberian snakes (two for each ring) and the spin rotators (four for each collider experiment) for RHIC. Each snake or spin rotator consists of four $2.4\,m$ long, $4\,T$ super-conducting helical dipole magnet modules each having a full 360 degree helical twist. Using helical magnets minimizes orbit excursions within the extend of the snake or spin rotator which is most important at injection energy. Nevertheless the bore of the helical magnets has to be 10 cm in diameter to accommodate the 3 cm orbit excursions.

Only a single Siberian snake in one of the two RHIC rings was available this year. This meant that vertically polarized protons needed to be injected without the snake powered, the snake was then turned on, which rotates the spin into the

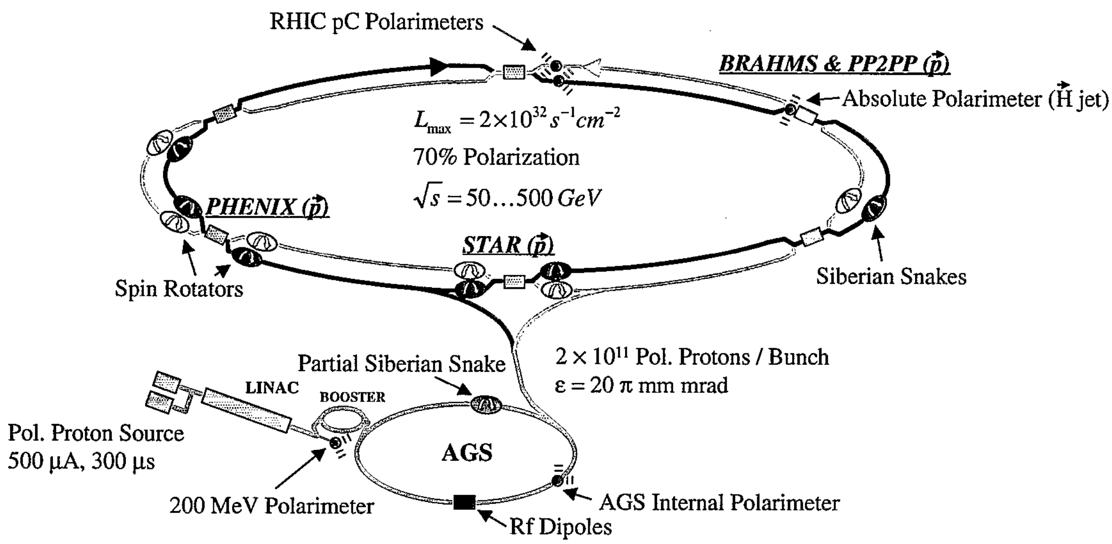

FIGURE 2. The Brookhaven hadron facility complex, which includes the AGS Booster, the AGS, and RHIC. The hardware for polarized proton operation in RHIC includes two snakes per ring, four spin rotators per detector for achieving helicity-spin experiments, a proton-carbon polarimeter per ring for beam polarization monitoring, and a polarized hydrogen gas jet for absolute polarization calibration.

horizontal plane, and then finally the beam was accelerated. Even under this more complicated scenario polarized protons were successfully accelerated to about 30 GeV, the highest energy accelerated polarized proton ever achieved. Fig.3 shows the beam polarization measured in RHIC during this first commissioning run. More than 20 years after Derbenev and Kodratenko made their proposal to use local spin rotators to stabilize polarized beams in high energy rings it has now been demonstrated that their concept is working flawlessly even in the presence of strong spin resonances at high energy. It also confirms the initial tests of the Siberian snake concept at low energy that were performed at IUCF.

In addition to maintaining polarization the fast, accurate, and reliable measurement of the beam polarization is of great importance. Very small angle elastic scattering in the Coulomb-Nuclear interference region offers the possibility for an analyzing reaction with a high figure-of-merit which is not expected to be strongly energy dependent. For polarized beam commissioning in RHIC an ultra thin carbon ribbon was used as an internal target and the recoil carbon were detected to measure both vertical and radial polarization component. H. Huang showed data from the operation of this high energy polarimeter that showed excellent particle identification. It was demonstrated that this polarimeter can be used to monitor polarization of high energy proton beams in a almost non-destructive manner.

For the upcoming polarized proton run it is planned to install all four Snakes

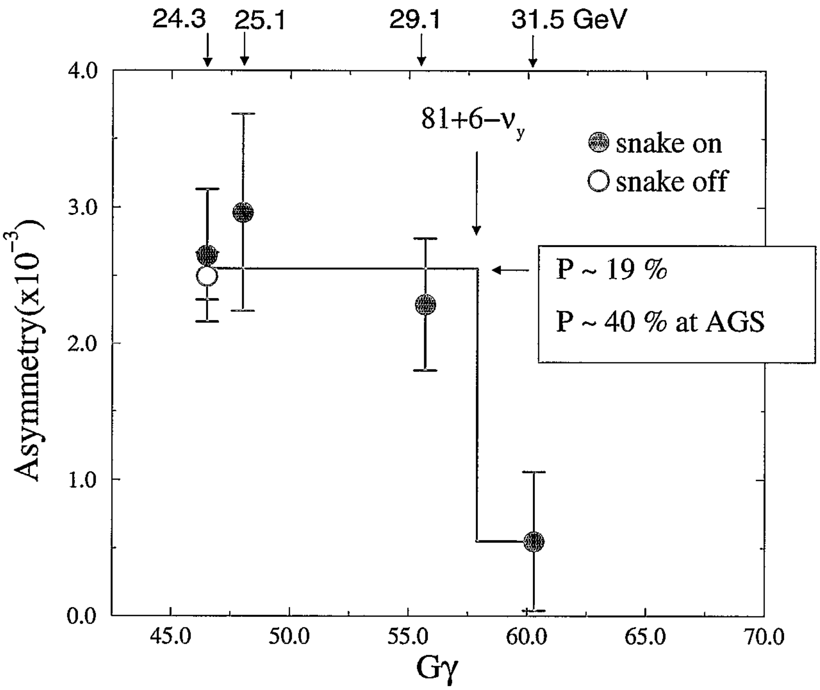

FIGURE 3. Measured polarization of the first polarized proton beam in RHIC at injection without Siberian snake (open circle) and accelerated with snake (filled circles). The graph shows the asymmetry measured with the RHIC proton-carbon polarimeter. The polarization values given were obtained from calibration measurements performed previously in the AGS. Significant polarization was lost at injection when the snake was off and at the first very strong spin resonance. Spin tracking indicates that this latter loss is due to an improper betatron tune setting and the large uncorrected closed orbit distortion.

as well as the proton-carbon polarimeter in the second ring. This should allow for acceleration to the full RHIC energy of 250 GeV. Collisions are planned at 100 GeV on 100 GeV at which energy one of the two snakes per ring can be turned off to produce longitudinal polarization at the detetors. The luminosity is expected to be about $5 \times 10^{30}\ cm^{-2}\ s^{-1}$.

RECORD HERMES DATA RUN
6 MILLION DIS EVENTS IN 2000

The HERMES experiment uses a polarized internal gas target in the HERA electron ring to collect deep inelastic scattering data. E. Aschenauer reported that this past year HERMES was able to break all records with increased target thickness and excellent HERA machine performance. Beam and target polarizations were typically about 55 % and 85 %, respectively.

Compared to the CERN SMC experiment the lower beam energy of about 28 GeV limits the range in x to about 0.01 and higher for the determination of the spin structure function but in this range the data is of very high quality and is in very good agreement with previous data from CERN and SLAC measurements. The recently collected deuteron data is expected to give very precise information on the g_1 spin structure function of the neutron.

The very high data rate and recent detector upgrades also allowed HERMES to expand the scope of DIS measurements. Measuring semi-inclusive production of hadrons, presumably coming from the struck parton, in principle allows the flavor decomposition of g_1. Also, pion production showed an azimuthal asymmetry around the direction of the struck parton, indicating that the fragmentation function is spin dependent and can be used to analyze the parton polarization.

NEXT PHASE OF PROTON SPIN STRUCTURE STUDIES TO BEGIN SOON

F. Bradamante discussed the plans for the new CERN experiment COMPASS. It is a major upgrade of the previous SMC experiment to include the detection of the hadrons produced in semi-inclusive polarized DIS. As described above for HERMES, semi-inclusive DIS in principle allows for the measurement of flavor separated quark spin structure functions. Open charm production from photon-gluon fusion will give access to gluon polarization. Also, using the spin-dependence of the fragmentation functions the quark transversity function h_1 should be accessible. The higher energy of the polarized CERN muon beam of about 200 GeV will make all of these measurements easier to analyze and also allows the measurement to be extended to lower x values. The experiment is scheduled to start in 2001.

Around the same time the first polarized proton collision at RHIC are scheduled to occur. N. Saito described the plans of the spin measurements of the two main RHIC detector collaborations STAR and PHENIX. At RHIC center-of-mass collision energies of 200 to 500 GeV the hard scattering events can be factorized similarly to DIS into a product of the spin structure functions of the two partons in the initial state, and the analyzing power of the hard interaction. If a leading hadron instead of a direct photon or jet is observed an additional fragmentation function for the production of this hadron has to be included.

Direct photon production from gluonic compton scattering in pp collisions will give direct access to the gluon polarization. This is the "gold plated" mode for both PHENIX and STAR and will give high precision data on the gluon polarization distribution from 0.01 to 0.2 for x.

The high energy will also allow the observation of W production from the interaction of a valence quark with a sea anti-quark. Since W production is a weak process it has a very large parity violating asymmetry which can be observed at RHIC for the first time. But it will also provide the direct measurement of the sea anti-quark polarization distribution of the proton.

It is planned to start with collisions at a center-of-mass energy of 200 GeV for the first two years and continue in 2003 with collisions at 500 GeV. Just like the semi-inclusive DIS measurements it is also possible at RHIC to use spin-dependent fragmentation functions to access transversity distributions. In this case the colliding proton beams will be vertically polarized.

CONCLUSIONS

With the stunning progress in the performance of polarized sources and the acceleration of polarized beams and several long standing major issues being addressed by ongoing experiments or experiments that are scheduled to start next year these are truly exciting times in spin physics.